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Impedance estimation from surface-based GPR reflection data

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High-resolution physical-parameter images of the shallow subsurface are important for various environmental applications. For example, the knowledge of the detailed hydrological-parameter distribution is key for groundwater and contaminant flow simulation. Surface-based ground-penetrating radar (GPR) is one of the most important geophysical techniques for high-resolution mapping of the subsurface structure in electrical-resistive environments. However, extracting information from surface-based GPR data on the physical parameters governing the wave propagation is challenging. Common tools such as common-mid point (CMP) velocity analyses can only provide images of limited resolution. We present a novel reflection-amplitude inversion workflow for surface-based GPR capable of resolving the subsurface dielectric permittivity distribution in markedly improved resolution. Our scheme is an adaptation of a seismic-reflection impedance inversion scheme to surface-based GPR. Key steps are relative amplitude-preserving data pre-conditioning including GPR deconvolution resulting in traces with the source-wavelet distortions and propagation effects largely removed. The subsequent inversion for the underlying dielectric permittivity structure is constraint with in situ dielectric permittivity data obtained by direct-push logging. Applications on realistic synthetic and field data demonstrate that our novel inversion scheme is capable of providing reliable physical-parameter images in a sub-wavelength resolution. For example, we mapped the shallow (3-7 m depth) dielectric permittivity structure of a sedimentary aquifer with decimeter resolution using 100 MHz GPR data. The resultant electrical-property models can, for example, by transformed to high-resolution water content or porosity maps, which are key for hydrological studies.